Design and Implementation of a high performance IPC for Intrusion Prevention using Socket API

Bachelorthesis

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Agenda

Motivation

Motivation

Host-based intrusion detection and prevention

Threats:

- access data,
- manipulate data, or
- render a system unreliable or unusable.

Host-based intrusion detection and prevention

Necessity for Intrusion Prevention Systems:

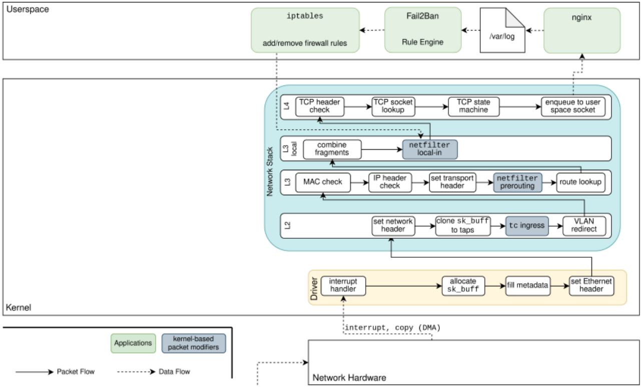
1. The majority of systems have vulnerabilities, rendering them susceptible.
2. Replacing systems with known vulnerabilities is difficult. Specific features may only be present in the less-secure system.
3. Developing absolutely secure systems is difficult, since the explicit absence of vulnerabilities can rarely be proven.
4. Secure systems remain vulnerable to insiders misusing their privileges.

Motivation - Fail2ban

Fail2ban application creates "jails":

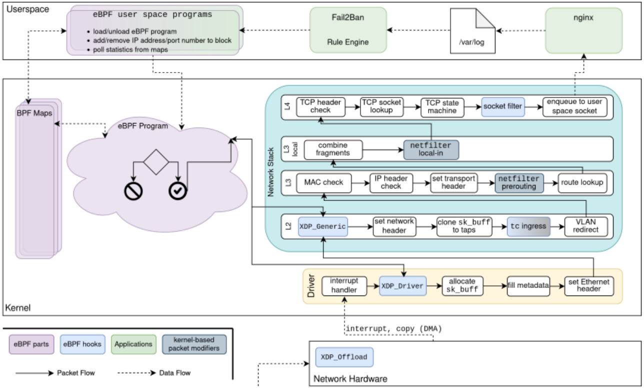
1. A jail consists out of:
    - Log path
    - Specific filter (uses Regex)
    - A defined action
    - Multiple customizable parameters (Ban duration, Ban limit)
2. Jails are saved on persistent storage
3. Deduces vital client information from log messages

Motivation - Fail2ban



Florian Mikolajczak: Implementation and Evaluation of an Intrusion Prevention System Leveraging eBPF on the Basis of Fail2Ban

Motivation - Fail2ban



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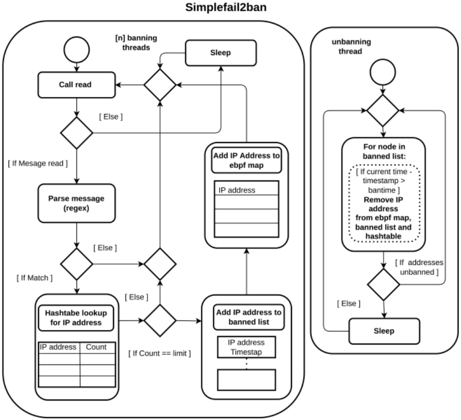

Paul Raatschen: Design and Implementation of a new Inter-Process Communication Architecture for Log-based HIDS for 100 GbE Environments

Design

Design

UNIX domain sockets

An alternative to the shared memory mode: UNIX domain Sockets

1. Preferred over internet sockets
2. Three types of UNIX domain sockets:
   - SOCK_STREAM: Stream-oriented socket. Establishes connections and keeps them open until explicitly closed.
   - SOCK_DGRAM: Datagram-oriented socket. Preserves message boundaries. Mostly reliable.
   - SOCK_SEQPACKET: Sequence-packet socket. Is connection-oriented, preserves message boundaries, and retains the order in which data was sent.

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Block

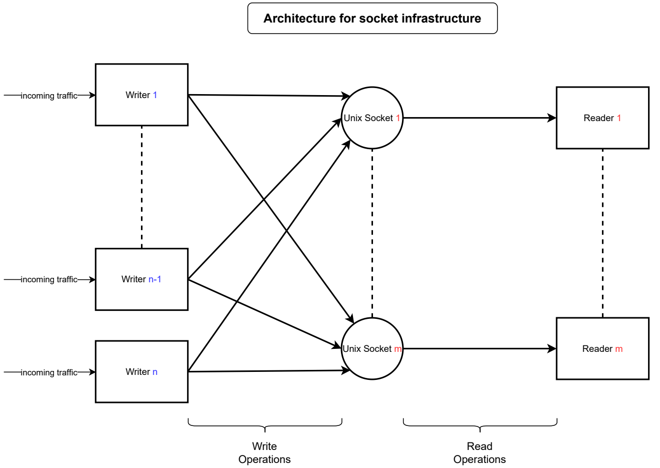
-> SOCK_SEQPACKET is preferred

UNIX domain sockets

An alternative to the shared memory mode:

1. Existing support on all UNIX systems
2. Established Write and Read API
3. Kernel-based IPC promising low latency and high bandwidth
4. Easily scalable beyond the local system

UNIX domain sockets



Implementation

Implementation

Shared parameters

Shared parameters:

```c
#define MAX_AMOUNT_OF_SOCKETS 32
#define SOCKET_TEMPLATE_LENGTH 128
#define SOCKET_NAME_TEMPLATE "/tmp/unixDomainSock4SF2B_"
```

Union defining which process is calling a function:

```c
union sock_arg_t{
    struct sock_writer_arg_t wargs;
    struct sock_reader_arg_t rargs;
};
```

Auxiliary functions

Initialization of socket IPC:

```
int sock_init(
    union sock_arg_t *sock_args,
    int role
);
```

Cleanup of socket IPC:

```
int sock_cleanup(
    union sock_arg_t *sock_args,
    int role
);
```

Write API

Writer structure:

```
struct sock_writer_arg_t
{
        char socketPathNames
              [MAX_AMOUNT_OF_SOCKETS][SOCKET_TEMPLATE_LENGTH];
        struct sockaddr_un
              socketConnections[MAX_AMOUNT_OF_SOCKETS];
        int socketRecvs[MAX_AMOUNT_OF_SOCKETS];
        int writeSockets[MAX_AMOUNT_OF_SOCKETS];
};
```

Write API

Write function:

```
int sock_writev(
        struct sock_writer_arg_t *sock_args,
        struct iovec *log_iovs,
        uint16_t invalid_count,
        uint16_t maxNumOfSocks
);
```

Read API

Reader structure:

```
struct sock_reader_arg_t
{
    char socketPathName[SOCKET_TEMPLATE_LENGTH];
    struct sockaddr_un address;
    int sizeOfAddressStruct;
    int readSocket;
    int clientSockets[MAX_AMOUNT_OF_SOCKETS];
};
```

Read API

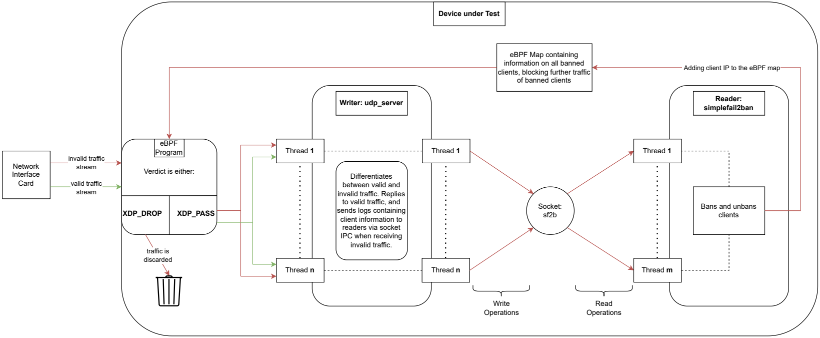
Read function:

```c
int sock_readv(
    struct sock_reader_arg_t *sock_args,
    struct iovec *iovecs
);
```

Experiments

Experiments

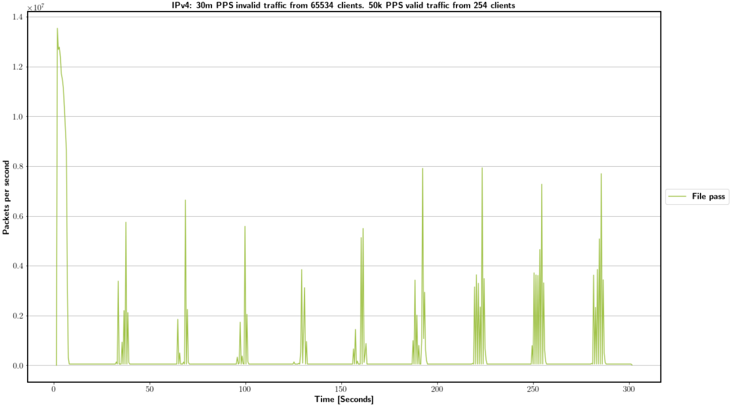
Device under Test


Device under Test
eBPF Map containing information on all banned clients, blocking further traffic of banned clients
Adding client IP to the eBPF map
Writer: udp_server
Reader: simplefail2ban
Network Interface Card
invalid traffic stream
valid traffic stream
eBPF Program
Verdict is either:
XDP_DROP
XDP_PASS
traffic is discarded
Thread 1
Thread n
Differentiates between valid and invalid traffic. Replies to valid traffic, and sends logs containing client information to readers via socket IPC when receiving invalid traffic.
Thread 1
Thread n
Socket: sf2b
Thread 1
Thread m
Bans and unbans clients
Write Operations
Read Operations

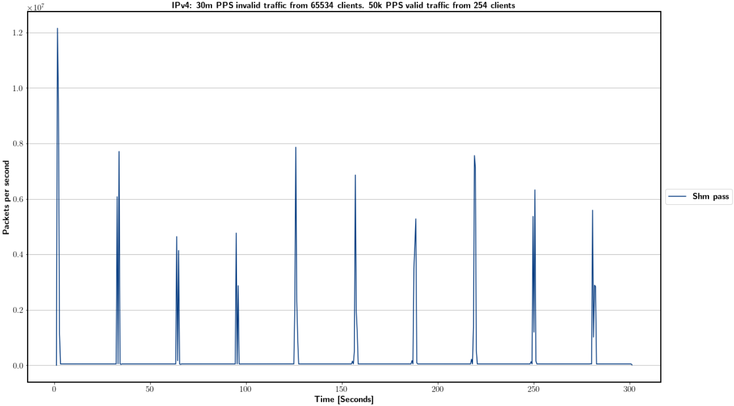
Factors and their levels

1. IP stack: IPv4, IPv6 and IPv4/IPv6 mixed
2. Effects of differing amount of invalid traffic sent: 100k, 1M, 10M, 20M, 30M PPS
3. Effects of differing number of clients sending invalid data: 65,534 (from 256 subnets) and 131,068 (from 512 subnets)
4. Differing IPC type: FILE (traditional file-based logging), SHM (using shared memeory), SOCK (using UNIX domain sockets)
    - If applicable: No 2nd Reader/ Enabling 2nd Reader

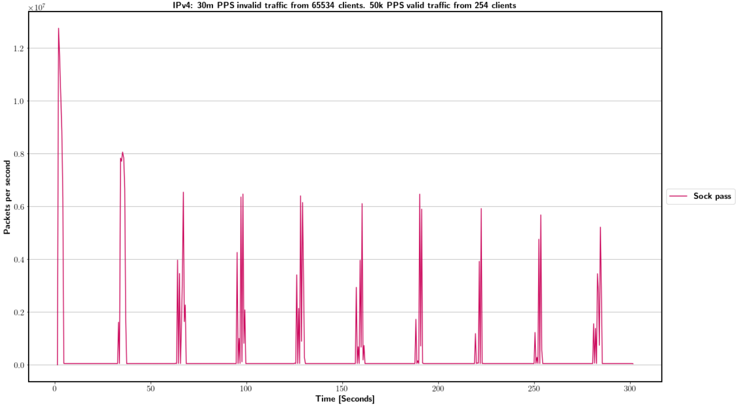
File pass: IPv4 - 65534 Clients - 30M invalid PPS



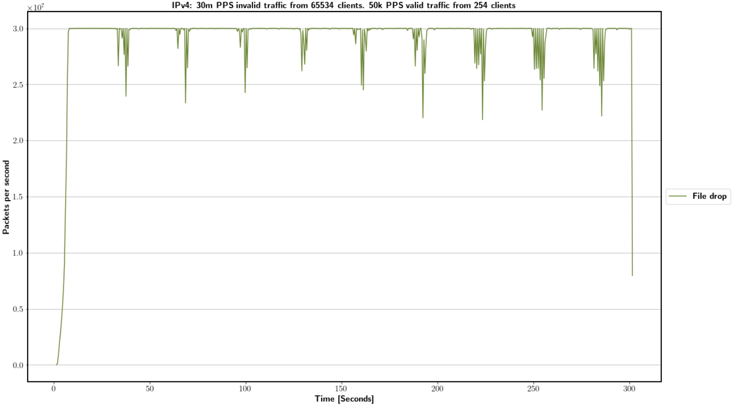
Shm pass: IPv4 - 65534 Clients - 30M invalid PPS



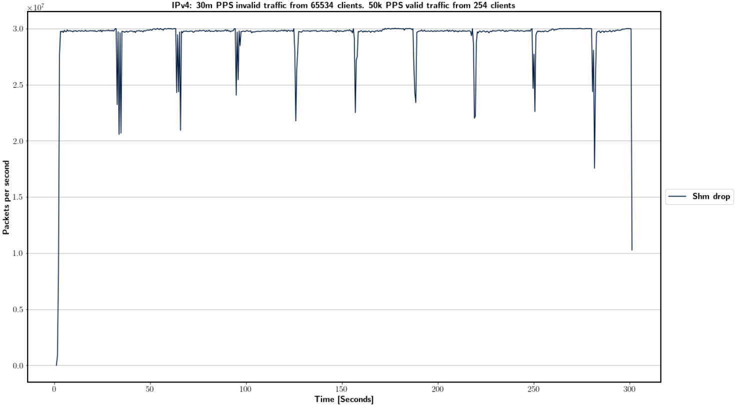
Sock pass: IPv4 - 65534 Clients - 30M invalid PPS



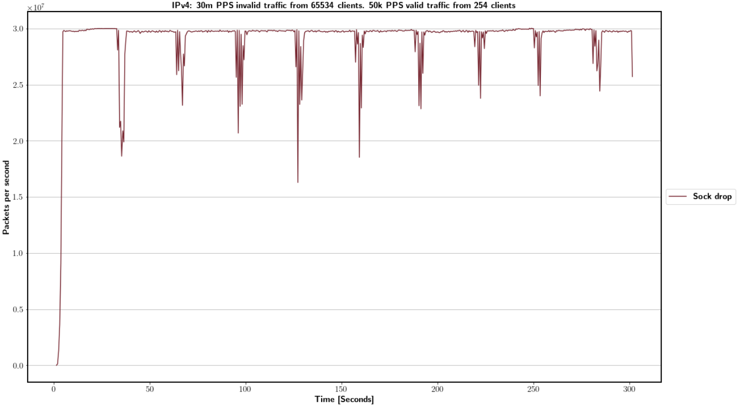
File drop: IPv4 - 65534 Clients - 30M invalid PPS



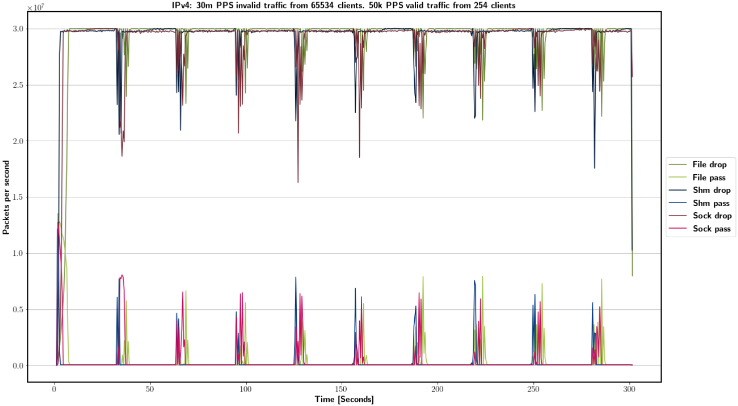
Shm drop: IPv4 - 65534 Clients - 30M invalid PPS



Sock drop: IPv4 - 65534 Clients - 30M invalid PPS



IPv4 - 65534 Clients - 30M invalid PPS - 50k valid PPS



IPv4 - 65534 Clients - 30M invalid PPS - 50k valid PPS

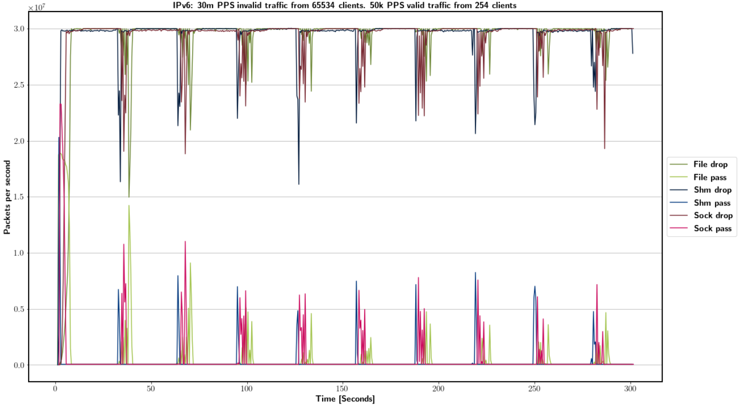
IPC type	XDP_DROP [10^8]	XDP_PASS [10^6]	Relative drop [%]
File	87.75	159.82	97.52375345
Shm	88.30	87.23	98.13105047
Sock	87.45	139.42	97.18179422

IPC type	Packets received by udp_server [10^6]	Log messages [10^6]	CPU [seconds]
File	17.48	4.07	16.55
Shm	21.39	6.99	39.08
Sock	16.92	3.16	138.85

Block

Total packets sent: 9,015m. Best-case drop rate: 99.97815533%

IPv6 - 65534 Clients - 30M invalid PPS - 50k valid PPS



IPv6 - 65534 Clients - 30M invalid PPS - 50k valid PPS

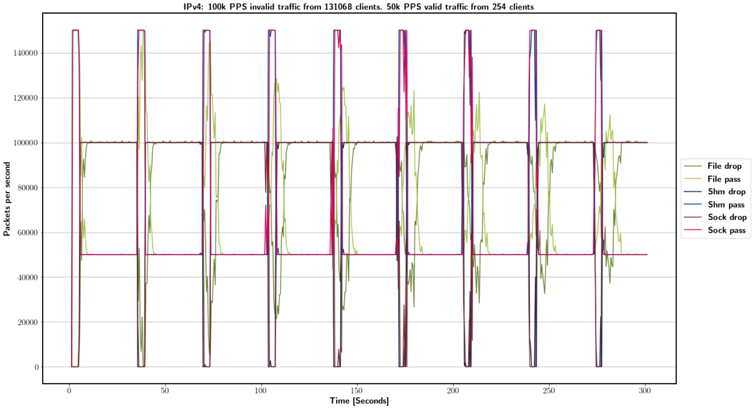
IPC type	**XDP_DROP [10^8]**	**XDP_PASS [10^6]**	**Relative drop [%]**
File	87.41	211.05	97.14091697
Shm	88.63	85.55	98.50239609
Sock	87.77	170.03	97.54838057

IPC type	**Packets received by udp_server [10^6]**	**Log messages [10^6]**	**CPU [seconds]**
File	17.20	3.87	22.51
Shm	21.79	7.24	46.03
Sock	16.92	3.00	149.69

Block

Total packets sent: 9,015m. Best-case drop rate: 99.97815533%

IPv4 - 131068 Clients - 100k invalid PPS - 50k valid PPS



IPv4 - 131068 Clients - 100k invalid PPS - 50k valid PPS

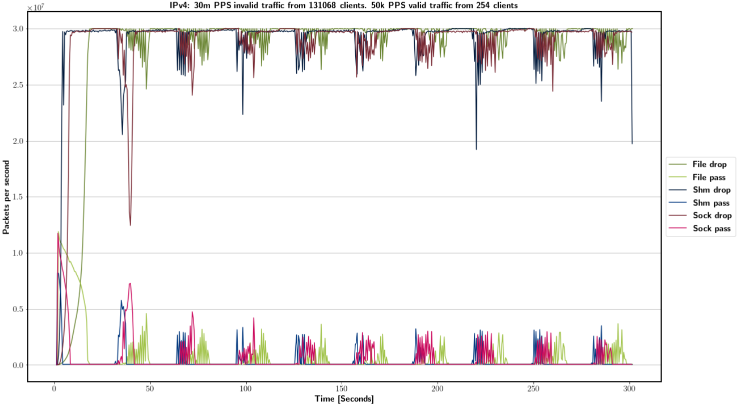
IPC type	XDP_DROP [10^6]	XDP_PASS [10^6]	Relative drop [%]
File	25.99	19.01	99.69409958
Shm	26.46	18.54	101.5083842
Sock	26.44	18.56	101.4395334

IPC type	Packets received by udp_server [10^6]	Log messages [10^6]	CPU [seconds]
File	18.16	3.54	08.34
Shm	18.54	3.54	10.14
Sock	18.53	3.54	100.40

Block

Total packets sent: 45m. Best-case drop rate: 86.8932%

IPv4 - 131068 Clients - 30M invalid PPS - 50k valid PPS



IPv4 - 131068 Clients - 30M invalid PPS - 50k valid PPS

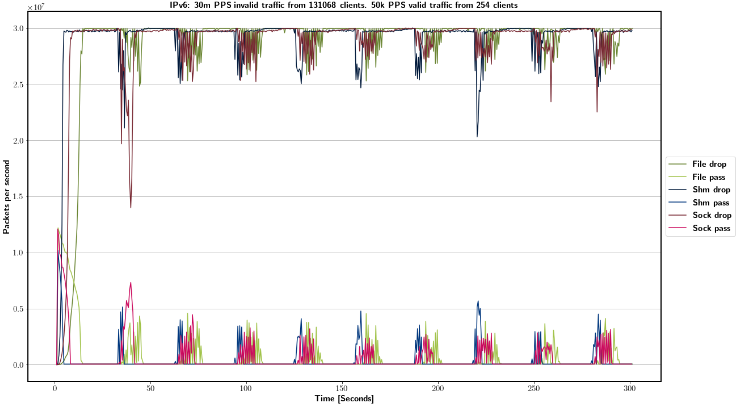
IPC type	XDP_DROP [10^8]	XDP_PASS [10^6]	Relative drop [%]
File	85.02	238.30	94.51036756
Shm	87.57	104.14	97.33826458
Sock	86.12	180.89	95.73084169

IPC type	Packets received by udp_server [10^6]	Log messages [10^6]	CPU [seconds]
File	18.04	7.44	38.99
Shm	25.32	11.50	71.92
Sock	18.33	5.93	323.02

Block

Total packets sent: 9,015m. Best-case drop rate: 99.95631067%

IPv6 - 131068 Clients - 30M invalid PPS - 50k valid PPS



IPv6 - 131068 Clients - 30M invalid PPS - 50k valid PPS

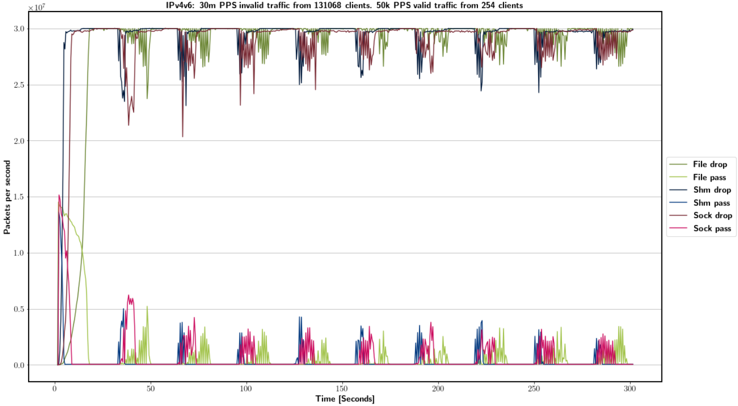
IPC type	XDP_DROP [10^8]	XDP_PASS [10^6]	Relative drop [%]
File	85.73	228.07	95.29278185
Shm	87.60	109.08	97.37706621
Sock	86.21	177.33	95.82614459

IPC type	Packets received by udp_server [10^6]	Log messages [10^6]	CPU [seconds]
File	17.90	6.91	38.41
Shm	25.08	11.15	74.71
Sock	18.67	6.18	317.37

Block

Total packets sent: 9,015m. Best-case drop rate: 99.95631067%

IPv4v6 - 131068 Clients - 30M invalid PPS - 50k valid PPS



IPv4v6 - 131068 Clients - 30M invalid PPS - 50k valid PPS

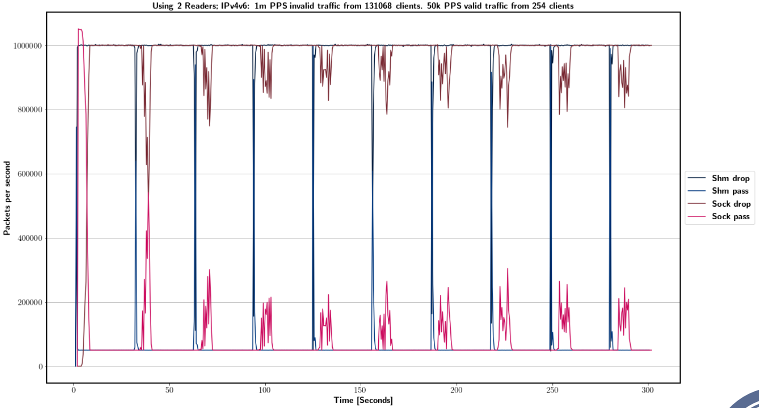
IPC type	XDP_DROP [10^8]	XDP_PASS [10^6]	Relative drop [%]
File	85.12	286.15	94.61335186
Shm	88.02	105.83	97.84149307
Sock	86.30	212.81	95.93428297

IPC type	Packets received by udp_server [10^6]	Log messages [10^6]	CPU [seconds]
File	17.69	7.07	47.15
Shm	25.13	11.16	94.64
Sock	18.00	5.99	353.34

Block

Total packets sent: 9,015m. Best-case drop rate: 99.95631067%

IPv4v6 2nd Reader - 131068 Clients - 1M invalid PPS - 50k valid PPS



IPv4v6 2nd Reader - 131068 Clients - 1M invalid PPS - 50k valid PPS

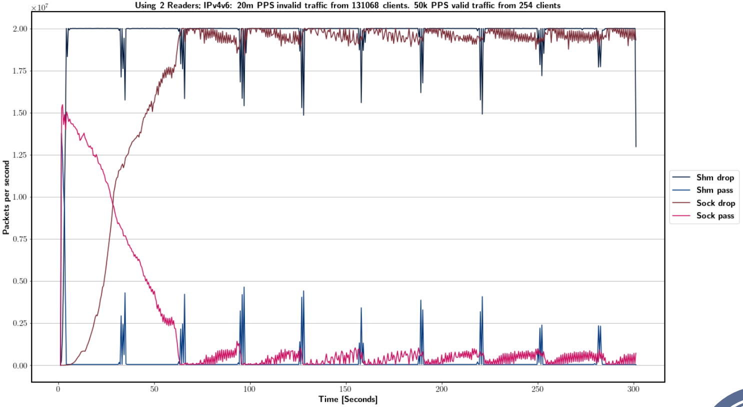
IPC type	XDP_DROP [10^7]	XDP_PASS [10^6]	Relative drop [%]
Shm	29.53	19.75	99.72283593
Sock	28.91	25.94	97.6334018

IPC type	Packets received by udp_server [10^6]	Log messages [10^6]	CPU [seconds]
Shm	19.48	4.49	17.76
Sock	18.29	4.15	80.82

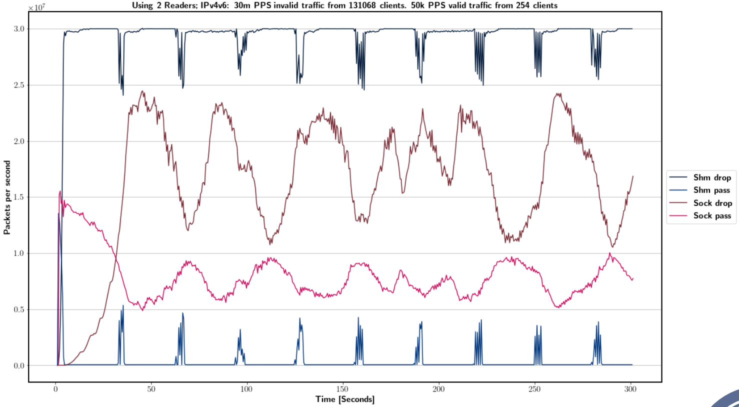
Block

Total packets sent: 9,015m. Best-case drop rate: 99.95631067%

IPv4v6 2nd Reader - 131068 Clients - 20M invalid PPS - 50k valid PPS



IPv4v6 2nd Reader - 131068 Clients - 30M invalid PPS - 50k valid PPS



Questions?

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